

ORIGINAL ARTICLE

Effects of body composition and basal metabolic rate the temporal parameters of ground reaction forces on gait of postmenopausal women

Efectos de la composición corporal y de la tasa metabólica basal en los parámetros temporales de las fuerzas de reacción terrestre en la marcha de las mujeres postmenopáusicas

Adriana Leite de Sousa^{1*}, Ronaldo Eugênio Calçadas Dias Gabriel², Florbela Rocha Aragão³, Aurélio Marques Faria⁴, Maria Helena Rodrigues Moreira⁵.

¹Federal University of Juiz de Fora, Faculty of Physical Education and Sports, Department of Gymnastic and Bodily Art, Brazil.

²University of Trás-os-Montes and Alto Douro, Department of Sport Sciences, Exercise and Health, Centre for the Research and Technology of Agro-Environment and Biological (CITAB), Portugal.

³Research Centre in Sports Sciences, Health and Human Development (CIDESD).

⁴University of Beira Interior, Department of Sport Sciences, Research Centre in Sports Sciences, Health and Human Development (CIDESD).

⁵University of Trás-os-Montes and Alto Douro, Department of Sport Sciences, Exercise and Health, Research Centre in Sports Sciences, Health and Human Development (CIDESD), Portugal.

*Correspondence: Adriana Leite de Sousa. Adresse: Street Adalgisa Gonçalves Soares, nº 128, neighborhood São Pedro – Juiz de Fora / MG - Brasil
- Phone: (55) 32-3237-1500 / E-mail : sousaleite@hotmail.com

Abstract

Objective: The study aims to identify and analyze the influence of body composition and basal metabolic rate over the behavior of temporal parameters of ground reactive forces during the gait of postmenopausal.

Methods: The experimental study was carry out with 52 women (± 59.8 years). The fat mass, abdominal visceral adiposity, skeletal muscle mass, fat-free mass and basal metabolic rate have evaluated by octopolar bioimpedance. The data for the ground reactive forces were collect through the force platform.

Results: In relative terms, the fat mass showed influence the final phase of support, causing a decrease in this parameter. Abdominal visceral adiposity also exerted inverse influence on the vertical loading ($r = -0.31$) and unloading ($r = -0.35$) rate. The skeletal muscle mass ($r = -0.45$, $r = -0.46$; $p < 0.01$) and basal metabolic rate ($r = -0.44$, $r = -0.46$; $p < 0.01$) influenced the vertical loading rate and the relationship between the vertical rates significantly.

Conclusion: The study suggests that the increase on fat mass and abdominal visceral adiposity, influence the support time and the vertical rates. With a more robust skeletal muscle system the postmenopausal women exhibit the phases of the gait cycle less accentuated, signaling less stress on the joints.

Key Words: Biomechanics, Metabolism, Obesity, Physical activity, Aging.

Resumen

Objetivo: El objetivo del estudio es identificar y analizar la influencia de la composición corporal y la tasa metabólica basal sobre el comportamiento de los parámetros temporales de las fuerzas reactivas del suelo durante la marcha postmenopáusica.

Métodos: El estudio experimental se realizó con 52 mujeres ($\pm 59,8$ años). La masa grasa, la adiposidad visceral abdominal, la masa muscular esquelética, la masa sin grasa y la tasa metabólica basal se han evaluado mediante bioimpedancia octopolar. Los datos de las fuerzas reactivas al suelo se recogieron a través de la plataforma de fuerza.

Resultados: En términos relativos, la masa grasa mostró influencia en la fase final de soporte, provocando una disminución en este parámetro. La adiposidad visceral abdominal también ejerció una influencia inversa sobre la carga vertical ($r = -0,31$) y la descarga ($r = -0,35$). La masa muscular esquelética ($r = -0,45$, $r = -0,46$; $p < 0,01$) y la tasa metabólica basal ($r = -0,44$, $r = -0,46$; $p < 0,01$) influyeron en la tasa de carga vertical y la relación entre las tasas verticales significativamente.

Conclusión: El estudio sugiere que el aumento de la masa grasa y la adiposidad abdominal visceral, influyen en el tiempo de soporte y las tasas verticales. Con un sistema de músculo esquelético más robusto, las mujeres posmenopáusicas exhiben las fases del ciclo de la marcha menos acentuadas, señalando menos tensión en las articulaciones.

Palabras Clave: Biomecánica, Metabolismo, Obesidad, Actividad física, Envejecimiento.

Received: 22 February 2017; Acept: 04 April 2017.

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

Research was supported by the Portuguese Foundation for Science and Technology through the project POCI/DES/59049/2004

Introduction

Obesity is a serious health problem and is associated to multiple co-morbidities and risk of disease, mainly in postmenopausal women (PWs). The proportion of abdominal fat tissue is a key correlate of the health risk associated to overweight and obesity (1). For PWs the increase in abdominal visceral adiposity (AVA), a characteristic of menopause, associated to a decrease in skeletal muscle mass (SMM) and in basal metabolic rate (BMR), lead to a deficiency in the cardiorespiratory ability (2,3).

The loss of muscle mass, one of the characteristics of aging is associated to a decrease in the strength, in the mass and the speed of contraction. After 50 years of age, the muscle mass decreases 1 to 2% a year and the strength 1.5% per year, rising to 3% after 60 years of age (4). In PW this decline, associated to a decrease in physical activity increases the risk of falls and consequently of osteoporotic fractures (5).

The TMB, a marker that reflects a combination of cardiopulmonary function and lean body mass resulting from regular physical activity, undergoes alterations from 20 years in women, with a reduction of 2% per decade, with a direct influence of the decline in SMM and an increase in body fat. On the transition to postmenopause, the time when there is an increase in body fat and visceral adiposity, BMR tends to reduce about 100kcal / day (6). Strategies aimed at improve muscle strength and lean body mass contributed to an improvement in bone health of women in physically active postmenopausal, signaling an intimate relationship of BMR with bone mineral density in this population (7,8).

The gait is an important and fundamental form of human locomotion. The analysis of the gait through the ground reactive forces (GRF) shows that there are several factors that influence the GRF such as age, menopause, obesity, and skeletal muscle condition (9 -12). They women, who experience natural menopause with a gradual decrease in the reduction of estrogen, indicate an accommodation of less abrupt external loads during gait. Postmenopausal users of hormone replacement therapy tend to present a transfer phase the support more pronounced and the lack of appropriate muscles to absorb and withstand the most intense external loads, could result in injury risks in this population (9).

Understanding the mechanical stresses to which the muscles and joints of they are exposed foot to every moment of the gait is fundamentally important for the autonomy and life quality of people, especially the PWs, due to the adverse gains from the ovarian failure. Similarly, the information about the time interval elapsing between the beginning and the end, between the phases of the gait cycle, the influences caused by body changes resulting from the natural aging they are also important contributions to the understanding of the time spent during the gait cycle in a given population.

Analyzing the relationship between body composition and the temporal parameters of the GRF it seems to be of fundamental importance in the definition of nutrition programs and exercise, to promote an improvement in the mechanical response ability to gait. The literature does not clarify the influence of the SMM, the fat-free mass (FFM), the fat mass (FM) as well as the BMR on the temporal parameters and rates of the GRF, during the gait the PWs. The study hypothesis is that with a robust musculoskeletal system postmenopausal women present rates and normal temporal parameters during gait. Therefore, the objective of the study is to identify and analyze the influence of body composition and BMR on the temporal parameters of the GRF during the gait of PWs.

Materials and Methods

This subset is part of the study “Shape Up During Menopause” which is a program that aims to promote physical activity and health in postmenopausal women. The eligibility criteria evaluated by assessing clinical history, were as follows: *a.* absence of premature, menopause (13); *b.* no significant hepatic, hematological, or renal disease; *c.* absence of cardiovascular diseases (symptoms of angina pectoris or myocardial infarction in the last 3 months) or uncontrolled hypertension (systolic arterial pressure >200 mmHg and diastolic arterial pressure >105 mmHg); *d.* nonuse of β -blockers and antiarrhythmic agents; *e.* nonexistence of skeletal muscle conditions, neuromuscular or neurophysiological diseases that could alter one’s participation in exercise or present aggravated symptoms in its execution; *f.* absence of deformities or sharp pain in the feet; *g.* nonexistence of acute trauma and surgery in the lower limbs; *h.* no diabetes-related peripheral neuropathy and ; *i.* inexistence of leg length discrepancies and cognitive, ocular and auditory disturbances.

The experimental design was approved by the University of Trás-os-Montes and Alto Douro and research was supported financially by the Portuguese Foundation for Science and Technology (reference POCI/DES/59049/2004).

All subjects gave their written informed consent to participate in the study, which conformed to the Declaration of Helsinki (14).

The sample included 52 postmenopausal women (15), aged between 48 and 68 years old (59.8 ± 4.5), the majority showing a natural menopause (85%), the use of hormone therapy (53.3%) and a time of menopause of 10.5 years. The natural menopause recognized after twelve consecutive months of amenorrhea, occurring without obvious pathological or physiological cause (15).

Measurement of Body composition

The BMR calculated using the Cunningham’s equation (16) with measurements performed in the morning by the same technician and following standard methodology. The skeletal muscle mass index ($SMI = SM/W \times 100$) was calculated according to Janssen (6).

Height were measured to the nearest 0.1 cm with de stadiometer SECA 220 (Seca Corporation, Hamburg, Germany), and body weight (BW) and skeletal muscle mass (SM) with the octopolar bioimpedance (InBody 720, Biospace, Seoul, Coreia do Sul), complying with preparation standards specified in the literature (17,18). The measurements they realized in the morning and after an overnight fast, by the same technician. There are still some contradictory results related to the assessment of fat mass (19,20).

Measurement of GRF

The data of the GRF were collected during gait in natural speed through a Kistler 9281B force platform (Kistler Instruments, Amherst, NY USA), with the recording of the force and discrete analysis of the two components of the GRF, on the anteroposterior (Y) and vertical (Z) directions, and their respective rates. Installed and leveled up with the ground, the platform connected to an analogic-digital conversion system BIOPAC Systems, at an acquisition rate of 1000 Hz with the data processed by the program AcqKnowledge 3.2.6 from BIOPAC Systems. All subjects wore comfortable clothes, were barefoot and performed in a single session 10 valid trials, on 8 meter straight and horizontal course, with the force platform installed in the middle. The obtained values normalized relative to the weight. The gait speed indirectly controlled through the total support time, not considered for analysis trials with a total support time over $\pm 5\%$ of intra-individual average (21).

Parameterization of the GRF

To better understand the strategies used by PWs to gain stability during displacement, the study analyzed the total support time F_z ($T_{\text{total}}F_z$), the relationship among the times that certain discrete parameters of vertical and anteroposterior forces occur, as well as some variation rates of the forces F_y and F_z , were measured (Figure 1). In particular, was measured the zero time (early records) to the first maximum vertical forces F_{z1} ; the time interval from the first maximum vertical force F_{z1} up to the minimum vertical force F_{z2} ; and the time interval from the minimum vertical force F_{z2} up to the second maximum vertical force F_{z3} (Figure 1). Among the variables allusive to the anteroposterior component, measured the time interval the time from zero up to force F_{y1} ; the measured the time interval from force F_{y1} to force F_{y2} ; and the measured the time interval from the point F_{y2} up to the force F_{y3} , were measured (Figure 1). The relationship among the times of the vertical forces TF_{z1}/TF_{z2} , TF_{z1}/TF_{z3} , TF_{z2}/TF_{z3} and the relationship among the time of the anteroposterior forces: T_{y1}/T_{y2} , T_{y1}/T_{y3} , T_{y2}/T_{y3} were measured.

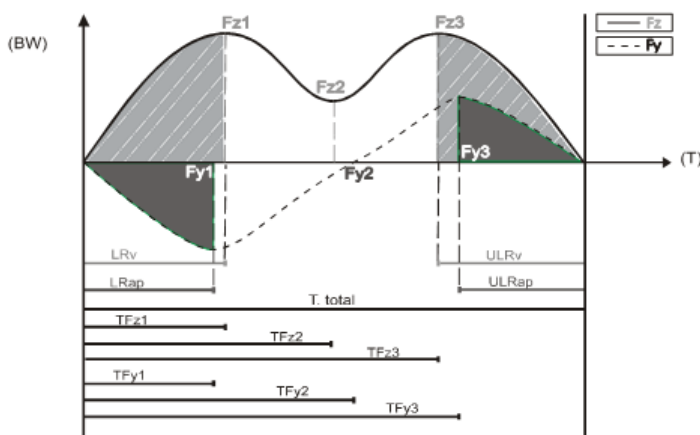


Table 1. Definition of the GRF parameters. Vertical force loading (LR_v) and unloading (ULR_v) rates. Anteroposterior force Loading (LR_{ap}) and Unloading (ULR_{ap}) rates. Times of vertical forces TF_{z1} , TF_{z2} , TF_{z3} and anteroposterior forces TF_{y1} , TF_{y2} and TF_{y3}

The rates of the vertical and anteroposterior component measured according to McCrory (22) and the values of the forces normalized for the body weight (BW). From the GRF vertical parameters, the rate of vertical load (LR_v) obtained by the amplitude of the first peak of the vertical component (F_{z1}) divided by the time interval in which the application of this force occurred TF_{z1} ($LR_v = F_{z1}/TF_{z1}$) was calculated.

The vertical unloading rate (ULR_v) was calculated by the amplitude of the second peak of the vertical component F_{z3} , divided by the total time of the GRF curve subtracted the time interval up to F_{z3} ($ULR_v = F_{z3}/T_{\text{total}}F_z - TF_{z3}$).

The rates of the anteroposterior component obtained by identical calculations made for the vertical component. The anteroposterior loading rate (LR_{ap}) was calculated considering the value of the first amplitude of the force of the anteroposterior component (F_{y1}), divided by the time interval in which the application of that force ($LR_{ap} = F_{y1}/TF_{y1}$) occurred. The anteroposterior unloading rate (ULR_{ap}) was calculated considering the value of the second force amplitude of the anteroposterior component (F_{y3}), divided by the total time of the GRF curve after subtracting the time interval up to F_{y3} ($ULR_{ap} = F_{y3}/T_{\text{total}}F_y - TF_{y3}$).

The calculation of the ratio between the vertical and anteroposterior force rates was obtained by dividing the vertical loading (LR_v) and vertical unloading rates (ULR_v), $RT_v = LR_v/ULR_v$ and anteroposterior loading (LR_{ap}) and anteroposterior unloading rates (ULR_{ap}), $RT_{ap} = LR_{ap}/ULR_{ap}$.

Statistical analyses

Statistical analysis performed using the Statistical Package for the Social Sciences program (version 22, SPSS Inc. Chicago, Illinois) and a significance level of 5% used for all tests. Unpaired student *t* tests used to examine differences among groups according to the cutoff values established in the literature for percentage FM, AVA, SMI, FFM with recourse to Mann-Whitney test when there was violation of normality (Shapiro Wilk Test).

The cutoff of the basal metabolic rate was defined in the study through a clusters analysis (K means).

Pearson correlation coefficients were calculated to assess the relationships between quantitative variables (HT, BMR, FM, AVA, SM, FFM) and the analysis of the association of biomechanical parameters with the ordinal variables (time of menopause and nature of menopause) was executed using the Eta. Variables that found to correlate with biomechanical parameters were included in the stepwise regression model.

Results

The age of the subjects ranged between 48,43 and 61,68 years old (table 1), and the mean values of the % of FM and the FFM were, respectively, 34,95 % and 42,75 kg and half of the sample showed the presence of obesity ($MG \geq 35\%$). The vast majority of the sample (86%) presented an elevated AVA index, $BMR < 1316$ kcal / day (69.2%) and normal muscle condition ($n = 52$).

Variables	Mean \pm SD	Range
Age (years)	59.83 \pm 4.53	48.43 – 68.61
Time of Menopause (years)	10.52 \pm 6.34	2.00 – 28.00
Basal Metabolic Rate (kcal/day)	1293.33 \pm 96.18	1125.39 – 1532.07
Body Composition		
Weight (kg)	65.31 \pm 9.11	44.62 – 89.04
Body Mass Index (kg/m ²)	27.06 \pm 3.73	18.69 – 36.35
Fat Mass (kg)	23.59 \pm 7.01	8.20 – 43.30
Fat Mass (%)	34.95 \pm 6.58	18.41 – 48.64
Visceral Fat Area (cm ²)	126.37 \pm 22.66	60.64 – 170.62
Skeletal Muscle Mass (kg)	23.37 \pm 2.69	18.68 – 29.85
Skeletal Muscle Mass Index (%)	35.52 \pm 3.65	28.08 – 43.95
Fat-Free Mass	42.75 \pm 4.46	35.00 – 53.80
Vertical Temporal Parameters		
TFz1/TFz2	0.51 \pm 0.04	0.44 – 0.64
TFz1/TFz3	0.32 \pm 0.03	0.26 – 0.45
TFz2/TFz3	0.63 \pm 0.04	0.54 – 0.72
LRv (BW/s)	6.90 \pm 1.31	3.59 – 10.41
ULRv (BW/s)	6.42 \pm 0.86	4.52 – 8.03
LRv/ULRv	1.08 \pm 0.17	0.53 – 0.68
Anteroposterior Temporal Parameters		
TFy1/TFy2	0.32 \pm 0.03	0.24 – 0.30
TFy1/TFy3	0.19 \pm 0.16	0.16 – 0.23
TFy2/TFy3	0.62 \pm 0.03	0.53 – 0.68
LRap (BW/s)	-1.85 \pm 0.35	-2.62 – -1.04
ULRap (BW/s)	2.19 \pm 0.49	1.31 – 3.76
LRap/ULRap	-0.87 \pm 0.19	-1.28 – -0.38

TFz/TFz - Relationship between the times of the forces Fz; **LRv** - Vertical loading rate; **ULRv** - Vertical unloading rate; **LRv/ULRv** - Relationship between the vertical loading and unloading rates; **TFy/TFy** - Relationship between the times of the force Fy; **LRap** - Anteroposterior loading rate; **ULRap** - Anteroposterior unloading rate; **LRap/ULRap** - Relationship between anteroposterior loading and unloading rates.

Table 1. Descriptive analysis (n= 52)

The correlation of biomechanical parameters with the menopause characteristics, body composition and BMR (table 2), showed that FM influenced temporal parameter TFz1/TFz3, which describes a ratio between the estimated duration of the support transfer phase and the support final phase. Also influenced temporal parameter as well as the parameter TFz2/TFz3, which describes the ratio between the approximate duration of the support intermediate phase and the time up to the end of the support intermediate phase and the start of the support pre-suspension phase. Presented an inverse correlation with the LRv rate ($r = -0.32$, $p < 0.05$), indicating a significant negative influence on this parameter.

Biomechanical Parameters	Age (years)	Time of Menopause (years)	Hormone Therapy (1,2) α	Nature of Menopause (1,2) α	Basal Metabolic Rate (kcal/day)	Fat Mass (kg)	Abdominal Visceral Adiposity (cm ²)	Skeletal Muscle Mass (kg)	Fat-Free Mass (kg)
TFz1/TFz2	-0.01	-0.15	0.00	0.00	0.13	0.14	0.10	0.14	0.13
TFz1/TFz3	0.05	-0.02	0.00	0.00	0.20	0.30*	0.26	0.21	0.20
TFz2/TFz3	0.07	0.15	0.00	0.00	0.16	0.27*	0.26	0.17	0.16
LRv (BW/s)	0.18	0.16	0.01	0.00	-0.44**	-0.32*	-0.31*	-0.45**	-0.44**
ULRv (BW/s)	0.07	-0.05	0.02	0.01	-0.07	-0.22	-0.35*	-0.08	-0.07
LRv/ULRv	0.11	0.25	0.01	0.00	-0.46**	-0.18	-0.05	-0.46**	-0.46**
TFy1/TFy2	0.03	0.04	0.04	0.00	0.22	-0.16	-0.23	0.22	0.23
TFy1/TFy3	-0.03	-0.02	0.02	0.00	0.20	-0.13	-0.17	0.20	0.20
TFy2/TFy3	-0.12	-0.08	0.03	0.00	-0.12	0.06	0.11	-0.12	-0.12
LRap (BW/s)	0.04	-0.01	0.00	0.02	0.24	0.03	0.10	0.24	0.24
ULRap (BW/s)	0.08	-0.09	0.06	0.03	0.02	0.01	-0.16	0.00	0.02
LRap/ULRap	0.06	-0.12	0.03	0.00	0.25	0.03	-0.08	0.24	0.25

TFz/TFz - Relationship between the times of the forces Fz; **LRv** - Vertical loading rate; **ULRv** - Vertical unloading rate; **LRv/ULRv** - Relationship between the vertical loading and unloading rates; **TFy/TFy** - Relationship between the times of the force Fy; **LRap** - Anteroposterior loading rate; **ULRap** - Anteroposterior unloading rate; **LRap/ULRap** - Relationship between anteroposterior loading and unloading rates; * $p < 0.05$; ** $p < 0.01$

Table 2. Correlation of biomechanical parameters with age, characteristics of menopause, basal metabolic rate and body composition

The increase of the AVA had a negative influence on the LRv rate ($r = -0.31$, $p < 0.05$), and signaled an inverse correlation with the ULRv rate ($r = -0.05$, $p < 0.05$).

The sample presenting a good muscle condition and energy expenditure, the variables SM, FFM and BMR showed an inverse correlation with the LRv rate ($r = -0.45$, $r = -0.44$, $r = -0.44$ respectively, $p < 0.01$) and LRv/ULRv rate ($r = -0.46$, $r = -0.46$, $r = -0.46$ respectively, $p < 0.01$).

The analysis of the influence of body composition in LR_v and LR_v/ULR_v rate (table 3), showed that the SMM ($\beta = -0.45$, $p < 0.01$) and ($\beta = -0.46$, $p < 0.01$) explained 18.4% e 19.3% of the variation in the dependent variable, with an estimated error of 11.87 BW/s and 0.15 BW/s.

Dependent Variable	Independent Variables (β)					Adjusted R ² × 100 (%)	SEE
	BMR (kcal/day)	FM (kg)	AVA (cm ³)	SMM (kg)	FFM (kg)		
LR _v (BW/s)	---	---	---	-0.45**	---	18.4	11.87
Dependent Variable	Independent Variables (β)					Adjusted R ² × 100 (%)	SEE
	BMR (kcal/day)			SMM (kg)	FFM (kg)		
LR _v /ULR _v	---			-0.46**	---	19.3	0.15

BMR – Basal metabolic rate; FM – Fat mass; AVA – Abdominal Visceral Adiposity; SMM – Skeletal muscle mass; FFM – Fat-free mass; LR_v – Vertical loading rate; ULR_v – Vertical unloading rate; Adjusted R² - Adjusted coefficient of determination; SEE - Standard error of the estimate; ** $p < 0.01$

Table 3. Influence of body composition (FM, AVA, SMM, FFM) in the variation of parameters temporal biomechanics and rate, with controlling for age, menopause and hormone therapy.

There was no significant correlation for the age, TM, hormone therapy and nature of menopause.

Discussion

As previously outlined in the introduction, this study aimed to identify and to analyze the influence of body composition and basal metabolic rate on the temporal parameters and rates of the GRF during the gait of PWs, with control of the age, TM, nature of menopause and hormone therapy. The rates of reactive forces support are very important data in the analysis of the gait is perhaps more important to your analysis than the analysis of the values of the forces themselves, as signal a greater or lesser accommodation capacity of external loads feet during the cycle of gait.

The present study shows (table 2) the LR_v rate suffers negative effect with the increased of AVA and the FM in PW's. The LR_v rate, which is the GRF parameter that describes the speed at which the vertical force increases during the support transfer phase from one foot to the other during the gait, showed a negative behavior less pronounced with the increase of AVA and FM in PWs, leading to a less pronounced loading. These data can be compared to those of the study by McCrory (22) in which the group submitted to a hip arthroplasty showed a lower value of the LR_v rate in the affected limb than the rate in the control group, signaling a more careful loading slowest. The analysis of these data shows that the AVA and the FM have an inverse correlation with the LR_v rate, and so the increased of these variables can contribute to the prediction of a less intense consequently slower rate during the gait of PWs.

Based on the established reference values for SMM, FFM and BMR, we compared the average values of the variables biomechanical temporal and rates of GRF. Regarding the hypothesis of the study, it expected that with better muscle condition, better FFM and higher energy expenditure, LR_v rates presented more markedly.

However, the results suggest that with a good muscle condition, in addition to a better FFM and better energy expenditure, the LR_v rate tends to has less pronounced in PWs. The increase in energy expenditure showed a slower loading, a lower LR_v rate. These data allow us to infer that an increase in the BMR, FFM and the SMM signals a decrease in the vertical force increment, suggesting a protective loading, because a better physical fitness has been associated to a greater protective behavior of the joints. With a more robust skeletal muscle system, the LR_v rate of PWs reaches that value more smoothly, signaling a protective effect of the lower limbs joints during the gait. Table 3 reinforces the finding, showing that the SMM is the most important correlation of the tested variables.

Therefore, the data reinforce the need for physical exercise programs, which increase energy expenditure and improve muscle condition, providing the PWs a comfortable walk, in a way to reach that parameter more smoothly. However, specific physical exercises for the lower limbs should be considered for this population as a way to decrease the chances of falls or sprains. This study is the first to provide data of the vertical parameters of ground reactive forces the gait PWs, with BMR.

The ULR_v rate, which is the GRF parameter that indicates the speed at which the vertical force decreases during the pre-suspension phase, also presented a negative correlation (table 2). This datum, can only be compared with other studies (9,22-26), which also analyzed the ULR_v rate during the gait. The PWs in the study presented an elevated index of AVA (126cm^2), signaling this variable as a significant influence on the behavior of the ULR_v rate, indicating it to lead to a slower unloading. Besides contributing to an increased risk of comorbidity, AVA accumulation also shown to be a predictor of a slower pre-suspension during gait PWs. Thus, the study reinforces the fundamental importance nutrition programs and physical exercise as prevention of possible falls and consequently a decrease of bedridden because of this body characteristic gain in this population.

Overweight which leads to biomechanical overload on the lower limbs contributing largely to articular disease (11), also interfere on the vertical temporal parameters of GRF in the gait of PWs. The relationship among the times of forces TFz_1/TFz_3 and TFz_2/TFz_3 showed a positive correlation with FM, suggesting that with the increase of FM the support transfer phase as well as the time interval up to the beginning of the support final phase, increase the respective relative contribution for the time interval that elapses between the beginning of the cycle and the start of the pre-suspension phase.

That is, in relative terms, the final phase of the support decreases with the increase of FM. Thus, the study indicates that the increase of FM contributes for a relative increase of the time interval elapsing from the beginning of the support transfer phase and the beginning of the support final phase. These data are consistent with previous studies showing that older adults with obesity tend to have a longer duration of support (11). In addition, the study indicated that the increased FM causes a slower final phase support in gait PWs.

The temporal parameters of the GRF were not as sensitive to the variables age, as well as the characteristics of the menopause, menopause time, menopause nature and hormone replacement therapy in this study. Thus, there was not a statistically significant correlation between these variables and the biomechanical parameters.

The study also showed that the increase in BMR, SMM and the FFM had an inverse effect on the relationship between the LR_v/ULR_v rates suggesting a less heterogenic accommodation of the external loads during the gait of PWs. The SMM showed to be the most influential variable in this parameter (table 3), showing the need for a greater protection of the skeletal muscle system to support the external loads variations. The analysis of these data shows that with a robust skeletal muscle system the PWs can possibly compensate for the external loads variations during the gait with less stress to the joints.

This study should be interpreted in the light of some limitations. In addition to being overweight, in transition to obesity and with a high AVA index, the PWs showed normal SMMI. This fact may be due to the representative level of physical activity of the population being study. Thus, the study suggests that more studies should be conducted with obese PWs have low and high BMR, and with PWs without the use of HT, as well as another method of fat mass measurement.

Conclusions

In conclusion, our data suggests that the body composition interferes significantly in the temporal parameters the GRF of the gait of PWs. Both FM and AVA caused reverse effects on vertical rates the temporal parameters the GRF during gait of PWs. With a more robust skeletal muscle system and consequently with a better energy expenditure, the PWs exhibited variations of external loads the initial contact and to take off the ground, signal a heel contact with the softer ground with less stress joint, indicating a more comfortable gait. Therefore, suggests that to promote healthy aging of these women, consider nutritional programs and specific exercise for this population, it contributes to greater longevity and a better autonomy in the daily lives of this population, in addition to promotion of pleasure in being active.

Acknowledgment

Research was supported by the Portuguese Foundation for Science and Technology through the project POCI/DES/59049/2004

References

- 1- Tchernof A, Despres JP. Pathophysiology of human visceral obesity: an update. *Physiol Rev*, 2013; 93(1): 359-404.
- 2- Aragão FR, Abrantes CG, Gabriel RECD, Sousa MF, Castelo-Branco C, Moreira MH. Effects of body composition and menopause characteristics on maximal oxygen uptake of postmenopausal women. *Menopause*, 2011; 18(11): 1-7.
- 3- Moreira MH, Passos B, Rocha J, Reis V, Carneiro A, Gabriel RECD. Cardiorespiratory fitness and body composition in postmenopausal women. *J. Hum Kinetics*, 2014; 43(1): 139-148.
- 4- Rolland Y, Vellas B. Sarcopenia. *Rev Med Interne*, 2009; 30(2): 150-160.
- 5- Poehlman ET, Toth MJ, Gardner AW. Changes in energy balance and body composition at menopause: a controlled longitudinal study. *Ann Intern Med*, 1995; 123(9): 673-675.
- 6- Janssen I, Heymsfield SB, Wang Z, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. *J Appl Physiol*, 2000; 89(1): 81-88.
- 7- Hsu W, Fan C, Lin Z et al. Effect of basal metabolic rate on the bone mineral density in middle to old age women in Taiwan. *Maturitas*, 2013; 76(1): 70-74.
- 8- Marin RV, Pedrosa MA, Moreira-Pfimer LD, Matsudo SM, Lazaretti-Castro M. Association between lean mass and handgrip strength with bone mineral density in physically active postmenopausal women. *J Clin Dens*, 2010; 13(1): 96-101.
- 9- Sousa AL, Gabriel RECD, Faria MA, Aragão FR, Moreira MH. Behavior of temporal parameters of the ground reaction forces for the walking of postmenopausal women. *A Bioeng Biomech*, 2015; 17(3): 119-127.
- 10- LaRoche DP, Millett ED, Kralian RJ. Low strength is related to diminished ground reaction forces and walking performance in older women. *Gait & Posture*, 2011; 33(4): 668-672.
- 11- Ko S, Stenholm S, Ferrucci L. Characteristic gait patterns in older adults with obesity-Results from the Baltimore Longitudinal Study of Aging. *J Biomech*, 2010; 43(6): 1104-1110.
- 12- Whittle MW. *Gait analysis an introduction*. Butterworth Heinemann Elsevier, 2007.
- 13- Shuster L, Rhodes D, Gostout B, Grossardt B, Rocca W. Premature menopause or early menopause: long-term health consequences. *Maturitas*, 2010; 65(2): 161-166.
- 14- WMA. Declaration of Helsinki: ethical principles for medical research involving human subjects. Fortaleza World Medical Association, 2013.
- 15- Harlow S, Gass M, Hall J, Lobo R, Maki P, Rebar R W, Sherman S, Sluss P, Villiers T. Group, SC. Executive summary of the stages of reproductive aging workshop +10: addressing the unfinished agenda of staging reproductive aging. *J Clin End & Metab*, 2012; 97(4): 1159-1168.
- 16- Cunningham JJ. Body composition as a determinant of energy expenditure: a synthetic review and a proposed general prediction equation. *A J Clin Nutr*, 1991; 54(6): 963-969.
- 17- Heyward VH, Wagner DR. *Applied Body Composition Assessment*. 2 ed. Champaign: Human Kinetics, 2004.
- 18- Biospace. *Inbody 720, the precision body composition analyser. User's guide*. Seoul: Biospace Co, Ltd, 2004.
- 19- Völgyi E, Frances A, Tylavsky A, Suominen H, Alén M, Cheng S. Assessing body composition with DXA and bioimpedance: effects of obesity, physical activity, and age. *Obesity*, 2008; 16(3): 700-705.
- 20- Gibson A, Holmes J, Desautels R, Edmonds L, Nuudi L. Ability of new octapolar bioimpedance spectroscopy analyzers to predict 4-component-model percentage body fat in Hispanic, black, and white adults. *A J Clin Nutr*, 2008; 87(2): 332-338.
- 21- Gabriel RC, Abrantes J, Granata K, Edmonds L, Nuudi L. Dynamic joint stiffness of the ankle during walking: gender-related differences. *Phys Ther Spor*, 2008; 9(1): 16-24.
- 22- McCrory JL, White SC, Lifeso RM. Vertical ground reaction forces: objective measures of gait following hip arthroplasty. *Gait & Posture*, 2001; 14(2): 104-109.
- 23- Winiarski S, Rutkowska-Kucharska A. Estimated ground reaction force in normal and pathological gait. *A Bioeng Biomech*, 2009; 11(1): 53-60.
- 24- Stacoff A, Diezi C, Luder G, Stüssi E, Quervain IA. Ground reaction forces on stairs: effects of stair inclination and age. *Gait & Posture*, 2005; 2(1): 24-38.
- 25- Stacoff A, Quervain IA, Luder G, List R, Stüssi E. Ground reaction forces on stairs part II: knee implant patients versus normal. *Gait & Posture*, 2007; 26(1): 48-58.
- 26- Larsen AH, Puggaard L, Hämäläinen U, Aagaard P. Comparison of ground reaction forces and antagonist muscle coactivation during stair walking with ageing. *J Electrom Kines*, 2008; 18(4): 568-580.